

ALIGNMENT OF cD-GALAXIES WITH THEIR SURROUNDINGS

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Abstract

For a sample of 122 rich Abell clusters we find a strong correlation of the position angle (orientation) of the first-ranked galaxy and its parent cluster. This alignment effect is strongest for cD-galaxies. Formation scenarios for cD galaxies, like the merging scenario, must produce such a strong alignment effect. We show some N-body simulations done for this purpose.

Introduction

Orientation effects like alignments might constrain initial conditions for the formation of clusters and their member galaxies. Cluster collapse models by Doroshkevich (1973) and Icke (1973) predict - if galaxies are formed during this collapse of shortly afterwards - an isotropic galaxy position angle distribution when the collapse process is symmetrical, but if this collapse is asymmetrical the galaxies are expected to be aligned with their cluster. It can be argued that the angular momenta of galaxies have changed little since this formation epoch, so observing the present distribution of the angular momenta teaches us something about this formation process. The angular momentum of a galaxy is aligned with the visual polar axis, i.e. the axis perpendicular to the disk for spirals and the short axis for ellipticals (Franx, Illingworth and Heckman 1989). On the sky we can only observe the 2-dimensional projection of galaxies, which gives us a position angle and an ellipticity, but gives us two possible polar axes. Still one hopes to be able to use position angle distributions with appropriate statistics to constrain formation models and initial conditions. As a first step we obtained position angles for the 10-20 brightest galaxies in a sample of rich Abell clusters, and did some preliminary N-body simulations on simple cluster collapse models in order to explain found alignment effects and other phenomena in clusters of galaxies.

Observed alignment effects

For a complete sample of 122 rich Abell clusters we obtained cluster position angles by scanning POSS-plates on the Leiden Astroscan machine. From the resulting digitized images galaxies were recognized semi-automatically. The cluster position angle is then obtained by Fourier-analysis of the azimuthal galaxy distribution (Rhee *et al.* 1990). The position angle of the member galaxies are calculated from the digitized galaxy images subtracted from the cluster images, by means of intensity weighted moments.

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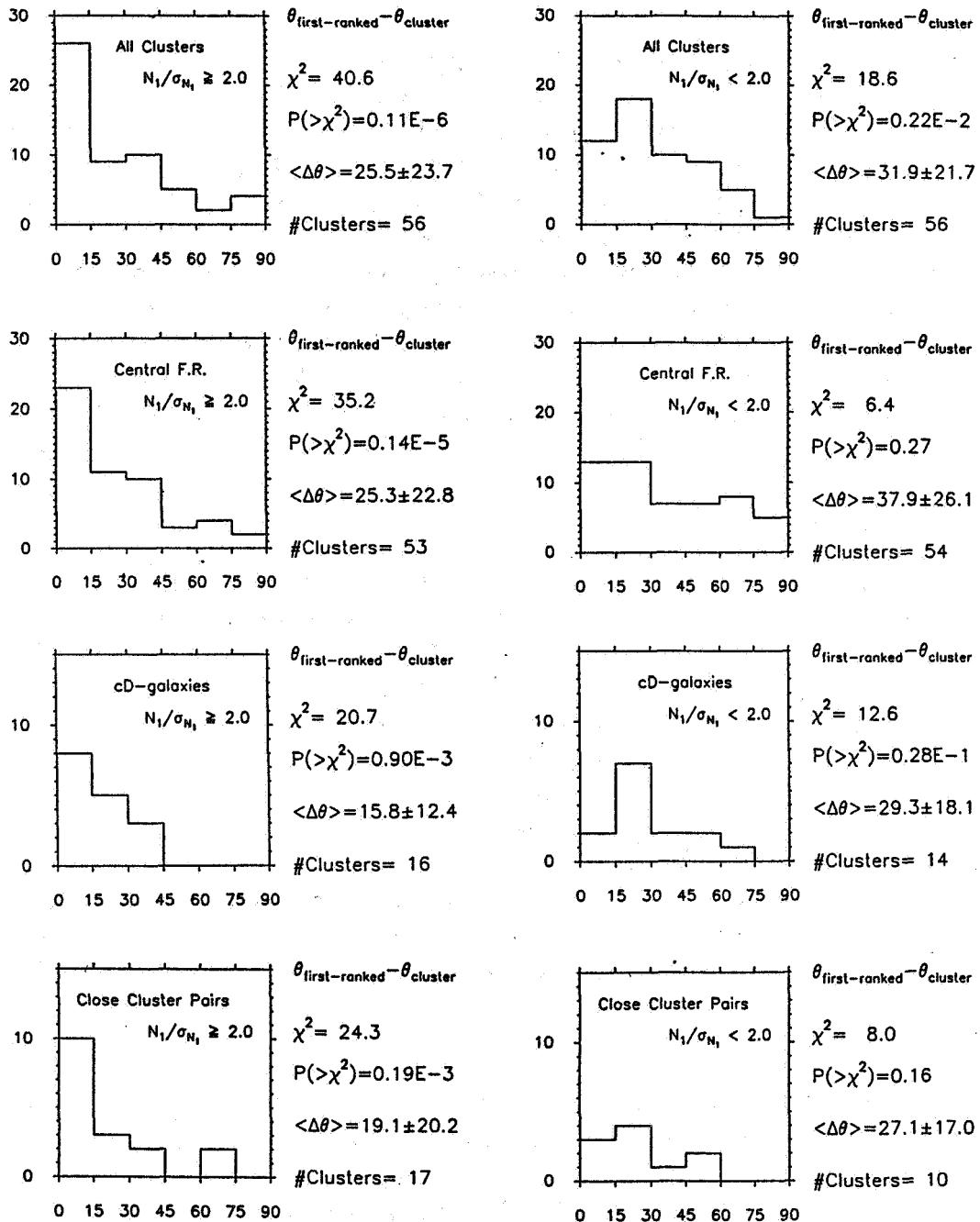


Figure 1

First-ranked galaxy alignment histograms showing the binned number distributions of the relative angle of the orientations of clusters and their first-ranked (brightest) galaxies. The left hand column shows elongated clusters (elongation strength $\frac{N_1}{\sigma_{N_1}} \geq 2.0$), the right hand column shows more spherical clusters ($\frac{N_1}{\sigma_{N_1}} < 2.0$). Each column consists of histograms for: a) all clusters, b) clusters with the first-ranked galaxy selected within 0.5 Mpc of the centre (central-first-ranked), c) clusters with a cD-galaxy as the first-ranked, and d) clusters in the 27 closest cluster pairs.

We find no preferred orientations or an alignment with the parent cluster for the 10-20 brightest galaxies except for the *first-ranked* galaxy (van Kampen and Rhee 1990). The observed first-ranked alignment effect is shown in figure 1 for several types of first-ranked galaxies. We divided our sample of clusters in two subsamples, 'elongated' and 'round' clusters, using an elongation strength parameter derived from the azimuthal galaxy distribution, as defined and obtained by Rhee *et al.* (1990).

The effect is much stronger for elongated clusters than for more spherical clusters. Without splitting up the sample part of the effect would be hidden. The scatter in alignment histograms is therefore partially due to the error in the cluster position angle (which is larger for more spherical clusters), but could also be caused by projection of intrinsic alignment effects. Further information on this - and other - alignment effect can be found in van Kampen and Rhee (1990).

First-ranked galaxies

The alignment found is an exclusive effect for the first-ranked galaxies, especially for cD-galaxies and other giant Brightest Cluster Ellipticals (BCE's). So these galaxies seem to play a special role in clusters of galaxies. Other evidence for an intimate connection of BCE's with their parent clusters is found in the fact that they are mostly sitting in the centre of the potential well, and show their ellipticity to increase strongly as a function of radius (Porter 1988). All this has to be produced by some formation scenario for giant first-ranked galaxies, like cluster collapse models or merging scenarios. One can imagine the formation of a giant galaxy at the centre of a collapsing aspherical protocloud. This asphericity continues down to the scale of the forming giant galaxy, thereby producing the alignment effect. During and after the formation, merging and cannibalism will have an effect on the evolution of the galaxy, and the question is what remains of the alignment effect. In order to find out, N-body simulations are a proper way of exploring this.

N-body simulations

As a start, Rhee and Roos (1989) studied the dissipationless collapse of a moderately aspherical initial system, using 4096 particles, evolved with the hierarchical tree-code written by Barnes and Hut (1986). The initial system is a homogeneous prolate ellipsoid (1:1:2) or a homogeneous oblate ellipsoid (1:2:2). The prolate simulation was also performed including substructure. They found in their simulations that the central part of the collapsed and virialized system does show the same orientation as the initial system if this initial system is *prolate*. This is shown in figure 2, where the prolate and oblate case can be compared. In figure 2 it is also shown how the effect of the increasing ellipticity as a function of radius found by Porter (1988) (see above) is produced by this simulations. Furthermore, the results does not differ if one starts with or without substructure.

The central part of the system could become the aligned first-ranked galaxy, thereby explaining the alignment effect. This first-ranked galaxy forming in the centre can grow further by merging, where dynamical friction causes victim galaxies to spiral in. In an elongated cluster, these inward orbits are preferentially elongated and aligned with the cluster.

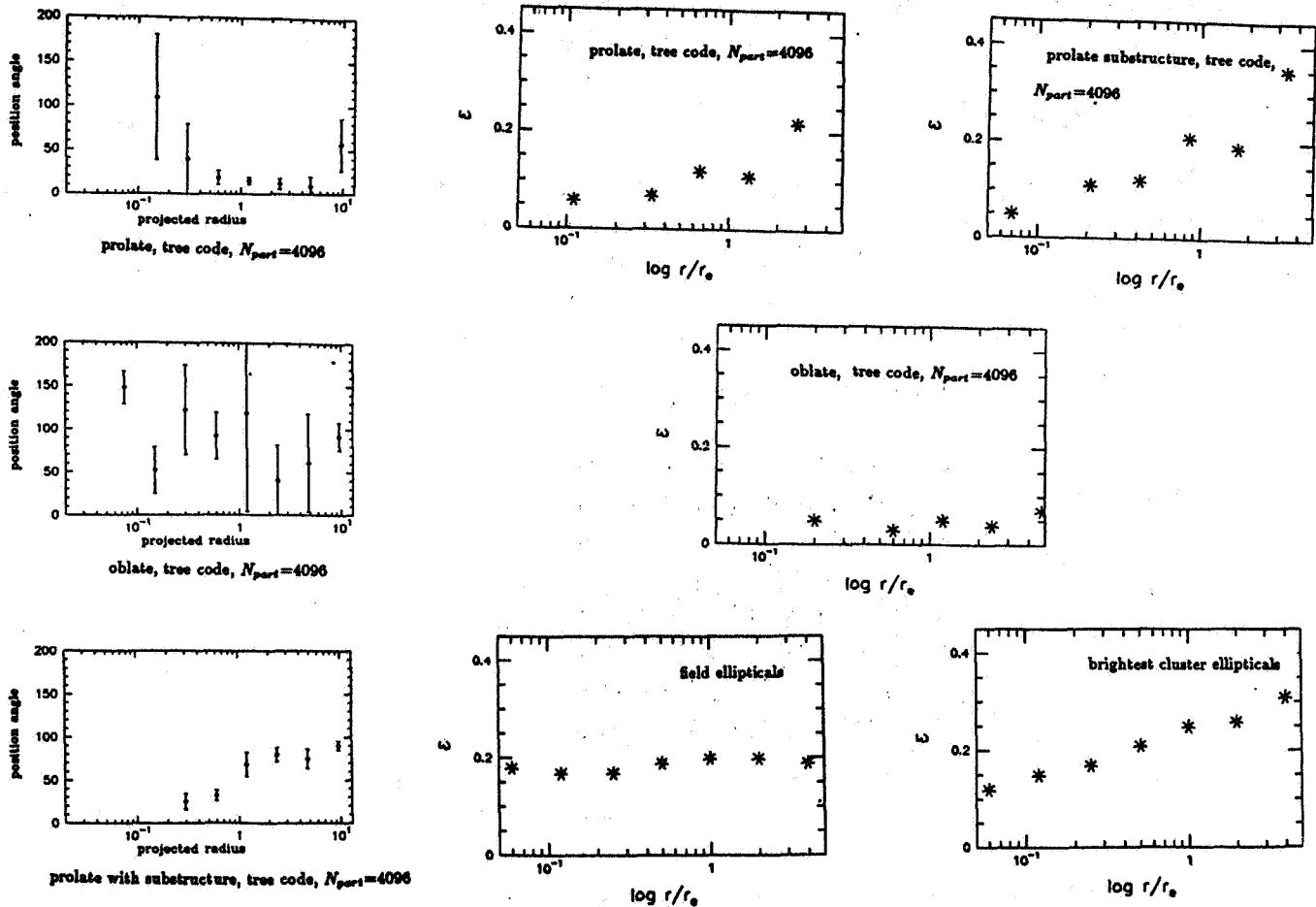


Figure 2

The results of N -body simulations performed by Rhee and Roos (1989). The three diagrams on the left show the position angle as a function of radius in the final distribution, for - from top to bottom - (a) a homogeneous prolate ellipsoid with an initial position angle of 0° , (b) a homogeneous oblate ellipsoid with an initial P.A. of 0° , and (c) a prolate ellipsoid containing substructure (homogeneous clumps) with an initial P.A. of 90° . For the cases (a) and (c) the P.A. is aligned with the initial P.A. over a range of 30 in radius. The other 5 diagrams show the comparison of simulations and observations with respect to the ellipticity as a function of radius. On top cases (a) and (c) as above, in the middle case (b), down left a sample of field ellipticals (Djorkovski 1985), and down on the right a sample of brightest cluster ellipticals (Porter 1988). As can be seen, cases (a) and (c), the prolate ellipsoids, generate what is observed. Of course this is not unique.

During this infall, the victims are stripped and contribute to the central giant (or cD) galaxy and its envelope, conserving or possibly increasing the found alignment effect with the surrounding galaxy distribution (the cluster). These predictions will be tested by us using more particles and a N-body code containing more physics. We will also start with more realistic initial conditions, like originating from a Cold Dark Matter spectrum.

Conclusions

We found the first-ranked galaxy of a cluster to be aligned with its parent cluster, especially cD-galaxies. This effect is strongest for elongated clusters, and exclusive for the first-ranked galaxy, which seems to play a special role in clusters. Resulting from N-body simulations, it was found that during the dissipationless collapse of an initially homogeneous ellipsoid, the information on the orientation is transferred to the centre if the initial mass distribution is prolate.

References

Barnes, J. and Hut, P. 1986, *Nature* **324**, 446
Djorkovski, S. 1985, Ph.D. Thesis, University of California at Berkeley
Doroshkevich, A.G. 1973, *Soviet Astr. - AJ* **16**, 986
Franx, M., Illingworth, G.D. and Heckman, T.M. 1989, submitted to *Astrophys. J.*
Icke, V. 1973, *Astron. Astrophys.* **27**, 1
van Kampen, E., and Rhee, G.F.R.N. 1990, submitted to *Astron. Astrophys.*
Porter, A.C. 1988, Ph.D. Thesis, California Institute of Technology
Rhee, G.F.R.N., van Haarlem, M.P., and Katgert, P. 1990, submitted to *Astron. Astrophys. Suppl.*
Rhee, G.F.R.N., and Roos, N. 1989, *Preprint*

DISCUSSION

Bland: To what extent are cD galaxies simply the density cusps at the cores of your collapsing ellipsoids? This is potentially important, since then we would have direct evidence that merged systems form something which in many respects looks like an elliptical galaxy.

Van Kampen: We don't pretend to simulate cD-formation, we just show that you can transfer orientational information over quite a large range (~30). My guess is that cD galaxies are mostly primordial, as single density cusps at the centers of collapsing ellipsoidal distributions, (if that is the way clusters form). But they certainly might grow by merging/cannibalism to become as giant as they are now. The observed alignment effect has to be maintained, of course, during this evolution.

Osterbrock: Your paper, like many others before it, shows the physical significance of cD galaxies, a classification type originally defined on completely empirical, morphological grounds by W. W. Morgan. In another paper, at this Colloquium, R. K. Kochhar mentioned that "nearly every SO galaxy seems to be peculiar." This is a point also previously made by Morgan; on morphological grounds he classified the so-called SO galaxies into several other different types, including D, E, and peculiar. I would suggest that researchers in the field of paired and interacting galaxies try analyzing their results in terms of Morgan's entire classification system, as well as the standard one, and see which one works best.

Van Kampen: I agree. With some communication between observers, collecting morphological data could be used to test morphology classifications, or even find a new one, which you would like to be as continuous as possible.

Smith: What was the mean isophotal magnitude at which your position angle determination for the first-ranked systems was made? Have you looked for the isophotal major-axis position-angle twists ($\Delta\theta/\Delta R$) seen in many ellipticals and cDs, and how sensitive is your conclusion to this effect?

Van Kampen: We determined galaxy position angles using intensity-weighted moments, with maximum weighting mostly between the 20th and the 22nd magnitude isophotes.